GEOLOGIC AND GEOMORPHOLOGIC ANALYSIS OF THE AREA OF THE MIRADOR CULTURAL AND NATURAL SYSTEM

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Introduction

This project, a study of the geologic and geomorphic context of the Mirador Basin archaeological project, is based on the premise that the unique habitation pattern of the Preclassic Maya within the project area is associated with the highly unusual physiography of the region. The Mirador cultural and natural area is one of a number of areas of channel-less drainage that characterize headwater areas of low relief within tropical/subtropical regions of the world. In addition, this area contains an unusual (perhaps unique) karst terrain that has developed within this climatic-geomorphologic terrain. Surface drainage is for the most part diffuse , with a general movement in the northern part of the Guatemalan section of the Basin towards the northwest. Subsurface drainage would appear to be relatively shallow (< 50m) at least at present. The distinctive bajos of the El Mirador area may well have formed as a result of the coalescence of small shallow solution/translocation pits and sinkholes which subsequently have been at least partly filled by alluviation during the Holocene.

It is axiomatic that bedrock lithology and structure are important determinants of physiographic patterns; thus a synoptic investigation of the physical environment of the El Mirador area, from both geologic and geomorphic perspectives, holds considerable potential for assisting in the overall understanding of Preclassic Maya settlement and use of this unique landscape.

Geologic Summary

The bedrock geologic framework of the Mirador region consists of the Buena Vista Formation, a calcareous unit of early Eocene age (i.e. about 50-60 million years old). This formation underlies (indeed it apparently forms) a very gently NW-sloping cuesta that extends from a prominent escarpment along its southern and eastern margins well into Mexico to the north and west. Dips of this formation as exposed along this escarpment and in the walls of sinkholes to the north are very shallow; dips over 5 degrees were observed in a few places and were to the north. Thus very slight open folding seems to be the predominant structural style.

The Buena Vista Formation consists of calcareous, dolomitic, and gypsiferous sedimentary deposits have generally been thoroughly and rather coarsely recrystallized to form well-indurated rocks. They have little porosity or permeability except where dissolution in the surficial karstic environment has produced solution channels of some kind.

The term Mirador Basin in the archaeological literature is reflected in four aspects of local geology: (1) old petroleum-industry cross-sections indicate that Tertiary units (i.e. Buena Vista Formation) seem to be slightly thicker in this area**;** 2) previous soils analyses have identified varied chemical compositions from soils surrounding the physical formations that form the natural framework of the area; 3) infrared satellite photographs that demarcate the geographical limits of the concentration of seasonally inundated lowlands known as bajos; and (4) these units are more gypsiferous in the Mexican part of the basin along the international border, implying a depositional basin in the Eocene. Thus the El Mirador region is indeed a structural and depositional basin in its Tertiary geology, although it is less apparent in its present physiography.

Geologic framework

The area of the Mirador Basin archaeological project is situated near the southern margin of the Yucatan Platform, which forms the peninsula of that name. The Mirador area is a tectonically stable area relative to the nearby margins of the platform to the south and east. These margin areas show signs of more recently active faulting (as reflected in both rock deformation and surface physiography). The nearest active zone to the south is called the La Libertad Arch. This zone, about 20 km wide, is oriented east-west and is situated between the northern shore of Lake Peten Itza and the southern margin of the platform (Vinson, 1962; Bonis and others, 1970; Case and Holcombe, 1980; Peterson, 1983). Northeast of the La Libertad Arch, the east-southeast margin platform (oriented NE-SW) passes near Tikal and Uaxactun, and is apparently a splay of the Rio Hondo fault zone. Further to the northeast, this zone becomes the boundary between the Yucatan peninsula and the Yucatan basin, and itself is a splay of the Caribbean-North American plate boundary (Case and Holcombe, 1980). This geometry implies that the escarpment between San Miguel and Uaxactun likely functions as an approximate margin to the region of tectonic stability. Maya-era earthquakes north and west of this escarpment have not been documented, but minor current seismic activity has been recorded (Kovach, 2004).

The bedrock formation that underlies the El Mirador area has gone under several names. Buena Vista Formation will be used here following Vinson (1962), who described these rocks is some detail (including fauna) and designated a type locality (on the north bank of the Rio San Pedro between Paso Caballos and San Miguel). Note that this description came from the petroleum-geology community in an era of active exploration. According to Vinson, the formation consists mostly of granular limestone and gypsum with some dolomite , pelletal and pseudo-oolitic limestone, limestone conglomerate, and gypsiferous clay. It is 300 meters thick at its type locality. An early Eocene age for the Buena Vista Formation is based on its foraminiferal microfauna. A Paleocene age is shown for the correlative unit (called Icaiche) in adjacent parts of Mexico (see references). These surface units are directly underlain by upper Cretaceous carbonate rocks; lower Cretaceous and Jurassic units are present at depth but the main area of thick Jurassic salt deposition is over 150 km to the west (Peterson, 1983).

Force traversed two sections through the Buena Vista Formation near of San Miguel, a small community located along the southern escarpment to the east of the type of the formation. These two sections were located only about 200 m apart. As bedding was nearly horizontal, stratigraphic position was established by elevation. Perhaps the most interesting aspect of these sections is how

much more strongly recrystallized the western section is relative to the nearby eastern section. Similar strongly recrystallized carbonate rock is also exposed in artificial exposures and the walls of big sinkholes. It appears that the recrystallization of carbonate rocks is widespread but local, preventing confident correlations and good descriptions of original rock types.

The Buena Vista formation is gently dipping everywhere it was observed, indeed most exposures show bedding that is within 2 degrees of horizontal. Two exposures of bedding dipping about 10 degrees to the north were measured about 6 km north of San Miguel. Apparently bedding is gently undulating and an enveloping surface dips gently north in the southern part of the study area, generally concordant to the land surface. Structural dips are unconstrained elsewhere except in one cross-section (which has been repeated by several authors) in Peterson (1983, fig. 7, location shown on fig. 3), which trends NE-SW along the western margin of the study area. This shows a marked thickening of Tertiary rocks in what Peterson termed the North Basin of Guatemala (which corresponds to the area of El Mirador Basin archaeological project). Peterson also shows a slight apparent dip to the SW near the international boundary , suggesting structural closure in this NE direction. The escarpment itself separates Buena Vista from older formations, thus structural closure of a basin in the Buena Vista Formation is available to the south, southeast, and northeast of the El Mirador area. However, geologic maps of Mexico (especially "Ciudad del Carmen") show the formation correlative with the Buena Vista overlain by a younger unit to the west, making structural closure to the northwest unlikely. These maps (especially "Merida") also show an increase in gypsum content of correlative Tertiary units along this boundary in the northern part of the El Mirador area, suggesting basinal deposition. Thus the area of which the El Mirador Basin archaeological project forms the center must be a basin in the geologic sense of both an Eocene depositional basin and an incompletely closed Eocene or later structural basin.

Surficial weathered unit

The blanket of weathered limestone overlying the formation is so thick, and has such different properties, that description of this weathered material (that formed the surface on which the Maya conducted their activities) is most pertinent to this project. This deeply and pervasively weathered material, locally called "tzaal", is generally a rather soft, porous, extremely calcareous material, and it is thought to be a product of the weathering of the Buena Vista Formation, rather than a stratigraphic unit. Locally it contains chert, and grades into exceptionally weathered and perhaps re-transported material ("sascab"). Its softness combined with its ability to form a casehardened surface were of course extremely valuable to a society with a Neolithic tool kit. However, these materials were not everywhere available; the nature of the weathered blanket varies with topographic setting. For example, the weathered material in some outer karstic zones has more the character of a solution-collapse breccia. Since this material was so extensively used by the Maya at all the archaeological sites of the basin, its proper description is one of the major opportunities of this project.

PHYSIOGRAPHIC FRAMEWORK

Physiographic Summary

The area of the Mirador Basin archaeological project lies near the southern margin of the Yucatan Platform, a tectonically stable area relative to the tectonic plate boundary region located immediately to the south and east. The El Mirador area lies near the crest and across the dip-slope of a broad (more than 50 km wide), low (generally less than 350 m high), generally northwest-sloping cuesta underlain by deeply-weathered, qypsiferous limestone. Regional slopes on this dip-slope are everywhere less than 1 percent, and local relief is generally less than 60 m.

The Mirador cultural and natural area is characterized by a highly unusual landscape, one that is perhaps unique in the world. One of a number of areas of channelless drainage that typify headwater areas of low relief within tropical/subtropical regions, the El Mirador area also supports an unusual, low-energy karst terrain that has developed within this climatic-geomorphologic terrain. Surface drainage is for the most part diffuse and indistinct, and subsurface drainage appears to be relatively shallow (generally less than 50m). The distinctive bajos of the El Mirador area likely formed as a result of the coalescence of small shallow solution/translocation pits and sinkholes which subsequently have been at least partly filled by alluvial deposits.

Comparative Geomorphic Analysis

Using full resolution Landsat 7 ETM data of tropical and sub-tropical areas (between 20°N and 20°S), Dohrenwend conducted a global search to identify and delineate areas that are physiographically and hydrographically analogous to the El Mirador region. As a result of this survey, areas of channelless drainage were identified and visually examined in several regions; however only three areas were found that contain useful analogues for the El Mirador region; and of these three, only one (the headwater region of the Zambezi River in southwest Zambia) is judged to be useful for comparative physiographic analyses.

Both the Zambezi headwater region and the El Mirador regions are broad upland plateaus of low relief. Local relief is generally less than 100m and regional gradients average substantially less than 1 percent. Both areas are subject to well-defined sub-tropical monsoonal climates, where surface flow is characteristically intermittent and highly seasonal. Geomorphic similarities between the two regions include: a) low to very low drainage densities; b) broad, gently-sloping interfluves with deep weathering profiles; c) large oval to curvilinear pans (shallow closed depressions often containing seasonal wetlands); d) broad, shallow, very gently sloping channelless drainageways aligned with and downslope from the pans; e) a conspicuous zonation of landforms progressing downslope (broad drainage divides to pans to broad channelless valleys to channeled valleys).

The geologic differences between the two regions are also instructive. The Zambezi headwater region is underlain by metamorphic cratonic rocks than are covered by a thin veneer of permeable continental clastic rocks. This geology is very different from the deeply weathered gypsiferous-limestone bedrock of the El Mirador region, However, karst-like depressions (certainly the most conspicuous and distinctive landscape element of both landscapes) are abundant in the headwater zones of both regions. These depressions and their strong association

with interfluves, indicate the importance of a combination of diffuse surface flow and subsurface flow processes in the formation and evolution of these low, gently sloping subtropical landscapes.

Preliminary Topographic Analysis

Using 3 arcsecond and 1 arcsecond SRTM digital elevation data and in combination with SPOT and Landsat ETM satellite image data, Dohrenwend also conducted a preliminary topographic analysis of the El Mirador region. Results of this preliminary analysis include:

1. A broad, subtle N25°W trending regional bulge extends from the area southeast of Tikal, through the general area of El Mirador, and then northwestward into Mexico. This bulge transects the two prominent fault zones, northwest and southeast of Tikal, that mark the boundary between the tectonically active region to the south and the tectonically quiescent region of El Mirador. The bulge is about 40 to 50 km wide and 100 to 150 meters high (relative to adjacent areas to the northeast and southwest). Average regional gradients transverse to this NNW-trending feature are everywhere less than 1%. In comparison, regional slopes trending from southeast to northwest are almost everywhere less than 0.05%.

2. Local relief in the El Mirador area ranges from less than10 m to as much as 60 m. Highest relief in the area occurs within a fairly well-defined zone about 30 km wide (from southwest to northeast) and 40 km long (from southeast to northwest) that is, not surprisingly, roughly coincident with the regional topographic bulge. It extends from a few km southeast of Nakbe, through El Mirador and then on into Mexico.

3. The area of the Mirador Basin archaeological project is comprised of at least six small watersheds (average size about 300 sq km). The low drainage divides between these watersheds are not well defined; however they are generally characterized by alignments of relatively small bajos and seasonal wetlands.

4. The watershed containing the site of El Mirador (the El Mirador watershed) is not well defined, and it may be, at least in part, an area of internal drainage. This watershed covers an area of about 270 sq km. However only about 170 sq km has the potential to contribute significant quantities of sediment to local areas of net alluviation. About 37% of the watershed is occupied by bajos; and most of these lowland areas show widespread indications of recent/active alluviation including: alluvial fans and broad, complex braided drainageways. Therefore even if one assumes a closed depositional system, one meter of upland denudation could result in no more than an average of about 1.7 meters of alluviation in the bajos. This may vary however, with the various containment systems such as the causeways and their proximity to alluvial flows which could account for more substantial alluviation in certain areas.

Future Directions in Research

Bedrock Geology

In view of the information and observations regarding the bedrock geology summarized abs already reached, and the difficulty of access to localities of further interest, further investigations of bedrock geology should proceed on an as-encountered basis centered on the question of rock types of the central basin. Emphasis of the geologic investigations should be on:

1. The nature of the overlying weathered material that was so important to the Maya given their toolkit (and perhaps detrimental to their agriculture in ways unknown to them). Establishing the vertical and lateral zonation of the material known as *tzaal* is an important opportunity.

2. Establishing the history of both natural and artificial filling of the bajos, in conjunction with David Wahl, Thomas Schreiner, and others

Geomorphology

Preparatory investigations (to be conducted primarily within the United States):

1. Using high-resolution aerial image data and SPOT satellite image data, develop a detailed drainage map of the El Mirador region. Drainage features delineated on this map will include: drainage divides, channels, bajos, channelless drainageways within bajos, areas of active alluviation within bajos, seasonal wetlands, perennial swamps, ponds sinkholes and possible areas of internal drainage.

2. Also using high-resolution aerial image data and SPOT satellite image data, develop a preliminary map of the El Mirador region showing all clearly recognizable indications of human activity including: causeways, rock quarries, quarried bajo margins, roads, modified drainageways, and all other prominent linear features. (Because this will be to some extent a subjective exercise, an ideal procedure would be for two or three individuals to map these features, then compare the results of these independent interpretations, and finally, rank the mapped features on the basis of this comparison).

Investigations to be conducted within Guatemala:

3. To develop additional information relating to the natural and anthropogenic features mapped in investigations (1) and (2) above, conduct stereoscopic examinations and digital scanning of historical aerial photography of the El Mirador area. Because historical aerial photographs are only available within Guatemala, this work will have to be conducted incountry.

4. If we are fortunate enough to be in Guatemala during that part of the wet season when a large tropical storm moves across the north Peten, and if we are fortunate enough to charter a fixed wing flight from Guatemala City over the north Peten immediately following such a storm, conduct an aerial reconnaissance of water flow and accumulation in the El Mirador region. (This activity would most likely occur in September October or November).

5. Field verification of widespread Bajo margin quarrying activity, to be conducted primarily in the dry season.

6. Field examination of selected areas of possible internal drainage in the El Mirador area (especially within the El Mirador subwatershed) and aerial examination of these areas. This might be best done at the onset of the rain periods (June).

7. Field examination, sampling, and analysis of any rock outcrops encountered during activities (5) and (6). (Quarried bajo margins would probably be among the more likely areas for bedrock outcrops in the region).

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